CLAIMS

1. A sound-amplification apparatus, comprising:

an acoustic signal source for outputting an acoustic signal;

an amplified sound source for receiving the acoustic signal from the acoustic signal source and radiating an amplified sound;

a control sound source provided in a vicinity of the amplified sound source for radiating a control sound; and

signal processing means for producing a control sound signal by controlling at least one of an amplitude and a phase of the acoustic signal from the acoustic signal source so that an acoustic space having a desired directionality is formed by interference between the amplified sound and the control sound, and providing the control sound signal to the control sound source.

2. A sound-amplification apparatus according to claim 1, the signal processing means comprising:

an error detector provided in a vicinity of the control sound source for detecting a synthesized sound between the amplified sound and the control sound;

directional radiation pattern selection means for selecting one of an output from the error detector and the acoustic signal from the acoustic signal source so as to obtain a predetermined directional radiation pattern; and

calculation means for producing the control sound signal by using the signal selected by the directional radiation pattern selection means, and

providing the control sound signal to the control sound source, wherein the calculation means is provided for:

when ensuring a directionality such that the amplified sound directed toward the error detector is reduced, producing, as a first control sound signal, a signal obtained by controlling the amplitude and the phase of the acoustic signal from the acoustic signal source so that the output signal from the error detector is 0;

when ensuring a dipole directional radiation pattern, producing, as a second control sound signal, a signal obtained by inverting the phase of the acoustic signal from the acoustic signal source;

when ensuring a non-directional radiation pattern, producing, as a third control sound signal, a signal having a same phase as that of the acoustic signal from the acoustic signal source; and

providing one of the first to third control sound signals to the control sound source as the control sound signal.

3. A sound-amplification apparatus according to claim 1, wherein the control sound source is provided along a same axis with the amplified sound source so that an acoustic radiation plane thereof is located symmetrically with an acoustic radiation plane of the amplified sound source.

4. A sound-amplification apparatus according to claim 2, wherein the error detector is provided along a straight line which passes through respective centers of the acoustic radiation planes of the amplified sound source and the control sound source.

5. A sound-amplification apparatus according to claim 2, the calculation means comprising:

a filtered-X filter for, where a transfer function of a space extending from the control sound source to the error detector is denoted by C, multiplying the acoustic signal output from the acoustic signal source by the transfer function C;

an adaptive filter for performing a convolution calculation on the acoustic signal from the acoustic signal source with a transfer function F, and providing the obtained calculation result to the control sound source as the first control sound signal; and

a coefficient updator for receiving an output from the directional radiation pattern selection means as an error signal, receiving an output from the filtered-X filter as a reference signal, updating a coefficient of the adaptive filter so that the error signal is small, and optimizing the transfer function F.

6. A sound-amplification apparatus according to claim 1, the amplified sound source comprising:

a horn driver for converting the acoustic signal from the acoustic signal source to an aerial vibration; and

a horn-shaped acoustic tube for continuously enlarging a wavefront of the aerial vibration output from the horn driver along a sound wave traveling direction.

7. A sound-amplification apparatus according to claim 1, the control sound source comprising:

a horn driver for converting the control sound

signal output from the signal processing means to an aerial vibration; and

a horn-shaped acoustic tube for continuously enlarging a wavefront of the aerial vibration output from the horn driver along a sound wave traveling direction.

8. A sound-amplification apparatus according to claim 6, wherein the acoustic tube includes a horn which is folded back at least once.

9. A sound-amplification apparatus according to claim 8, wherein the number of times the acoustic tube is folded back is an odd number.

10. A sound-amplification apparatus according to claim 7, wherein the acoustic tube includes a horn which is folded back at least once.

11. A sound-amplification apparatus according to claim 10, wherein the number of times the acoustic tube is folded back is an odd number.

12. A sound-amplification apparatus, comprising:

a concave reflector; and

a sound source provided within the reflector so as to be unidirectional toward a center of the reflector.

13. A sound-amplification apparatus according to claim 12, wherein

the sound source includes a control sound source for outputting a control sound and an amplified sound

source for outputting an amplified sound, the apparatus further comprising:

an acoustic signal source for outputting an acoustic signal; and

signal processing means for producing a control sound signal by controlling at least one of an amplitude and a phase of the acoustic signal from the acoustic signal source so that an acoustic space having a desired directionality is formed by interference between the amplified sound and the control sound, and providing the control sound signal to the control sound source.

14. A sound-amplification apparatus according to claim 13, the signal processing means comprising:

an error detector provided in a radiation space of the control sound from the control sound source for detecting a synthesized sound between the amplified sound and the control sound;

a filtered-X filter for, where a transfer function of an acoustic space extending from the control sound source to the error detector is denoted by C, multiplying the acoustic signal output from the acoustic signal source by the transfer function C;

an adaptive filter for performing a convolution calculation on the acoustic signal from the acoustic signal source with a transfer function F, and providing the calculation result to the control sound source as the control sound signal; and

a coefficient updator for receiving an output from the error detector as an error signal, receiving an output from the filtered-X filter as a reference signal, updating a coefficient of the adaptive filter

so that the error signal is small, and optimizing the transfer function F.

15. A sound-amplification apparatus according to claim 13, further comprising signal correction means for performing at least one of a delay control, an amplitude control and a phase control on the acoustic signal output from the acoustic signal source, and providing a resultant signal to the amplified sound source.

16. A sound-amplification apparatus according to claim 15, the signal processing means comprising:

an error detector provided in a radiation space of the control sound from the control sound source for detecting a synthesized sound between the amplified sound and the control sound;

a filtered-X filter for, where a transfer function of an acoustic space extending from the control sound source to the error detector is denoted by C, multiplying the acoustic signal output from the acoustic signal source by the transfer function C;

an adaptive filter for performing a convolution calculation on the acoustic signal from the acoustic signal source with a transfer function F, and providing the calculation result to the control sound source as the control sound signal; and

a coefficient updator for receiving an output from the error detector as an error signal, receiving an output from the FX filter as a reference signal, updating a coefficient of the adaptive filter so that the error signal is small, and optimizing the transfer function F, wherein

where the delay control is performed, the signal correction means performs the delay control with a delay time which corresponds to an amount of time required for the control sound radiated from the control sound source to reach the error detector.

17. A sound-amplification apparatus according to claim 16, wherein the transfer function F of the adaptive filter is expressed as -G/C, where G denotes an acoustic transfer function from the amplified sound source to the error detector.

18. A sound-amplification apparatus according to claim 13, wherein the control sound source is provided along a same axis with the amplified sound source so that an acoustic radiation plane thereof is located symmetrically with an acoustic radiation plane of the amplified sound source.

19. A sound-amplification apparatus according to claim 14, wherein the error detector is provided along a straight line which passes through respective centers of the acoustic radiation plane of the amplified sound source and the control sound source.

20. A sound-amplification apparatus according to claim 16, wherein the error detector is provided along a straight line which passes through respective centers of the acoustic radiation plane of the amplified sound source and the control sound source.

21. An on-vehicle sound-amplification apparatus, comprising:

a dipole sound source provided in a vicinity of a position of a passenger wherein at least one acoustic radiation axis thereof is directed outwardly from a vehicle interior; and

signal processing means for amplifying an acoustic signal and then inputting an output thereof to the dipole sound source.

22. An on-vehicle sound-amplification apparatus according to claim 21, further comprising:

a non-directional sound source provided in a vicinity of a center of the dipole sound source wherein an acoustic radiation thereof is driven to have an inverted phase from that of the acoustic radiation of the dipole sound source which is directed into the vehicle interior, wherein

the output from the signal processing means is also input to the non-directional sound source.

23. An on-vehicle sound-amplification apparatus according to claim 21, wherein:

the dipole sound source includes at least two loudspeakers wherein the at least two loudspeakers are arranged so that respective acoustic radiation planes thereof are directed opposite to each other; and

the signal processing means variably controls a phase of an input to at least one of the loudspeakers included in the dipole sound source.

24. An on-vehicle sound-amplification apparatus according to claim 23, wherein: each of the at least two loudspeakers included in the dipole sound source has an acoustic tube whose cross-sectional area along a

direction perpendicular to a sound wave traveling direction varies continuously; the acoustic tubes of the respective loudspeakers are arranged so that respective acoustic radiation planes thereof are directed opposite to each other; and a radiated sound from the loudspeaker which is driven by an output from the signal processing means is radiated by being guided along the acoustic tube.

25. An on-vehicle sound-amplification apparatus according to claim 23, the signal processing means comprising:

a radiation sound detector provided in a vicinity of a first one of the at least two loudspeakers included in the dipole sound source;

an error detector provided in a vicinity of a second one of the loudspeakers included in the dipole sound source;

an adder for adding together respective outputs from the radiated sound detector and the error detector; and

calculation means for receiving the acoustic signal and the output from the adder, performing a calculation so that the output from the adder is small, and inputting the obtained result to the second loudspeaker located in the vicinity of the error detector, wherein

the acoustic signal is input to the first loudspeaker located in the vicinity of the radiated sound detector.

26. An on-vehicle sound-amplification apparatus according to claim 25, the calculation means

comprising:

an adaptive filter for receiving the acoustic signal;

a filter for receiving the acoustic signal; and

a coefficient updator for receiving the output from the adder and an output from the filter, wherein:

an output from the adaptive filter is input to the second loudspeaker located in the vicinity of the error detector;

the coefficient updator updates a coefficient of the adaptive filter by performing a calculation so that the output from the adder is small; and

the filter has a characteristic equal to a transfer function from the error detector to the second loudspeaker located in the vicinity of the error detector.

27. An on-vehicle sound-amplification apparatus according to claim 23, the signal processing means comprising:

a radiated sound detector arranged in a vicinity of a first one of the at least two loudspeakers included in the dipole sound source;

a first error detector arranged in a vicinity of a second one of the loudspeakers included in the dipole sound source;

a second error detector arranged in a vicinity of the non-directional sound source;

signal correction means for receiving an output from the second error detector;

a first adder for adding together an output from the radiation sound detector and an output from the first error detector;

a second adder for adding together the output from the first error detector and an output from the signal correction means;

first calculation means for receiving the acoustic signal and an output signal from the first adder, and performing a calculation so that the output signal from the first adder is small, wherein an output therefrom is input to the second loudspeaker located in the vicinity of the first error detector; and

second calculation means for receiving the acoustic signal and an output signal from the second adder, and performing a calculation so that the output signal from the second adder is small, wherein an output therefrom is input to the non-directional sound source, wherein

the acoustic signal is input to the first loudspeaker located in the vicinity of the radiation sound detector.

28. An on-vehicle sound-amplification apparatus according to claim 27, the first calculation means comprising:

a first adaptive filter for receiving the acoustic signal;

a first filter for receiving the acoustic signal; and

a first coefficient updator for receiving the output from the first adder and an output from the first filter, wherein:

an output from the first adaptive filter is input to the second loudspeaker located in the vicinity of the first error detector;

the first coefficient updator updates a

coefficient of the first adaptive filter by performing a calculation so that the output from the first adder is small; and

the first filter has a characteristic equal to a transfer function from the first error detector to the second loudspeaker located in the vicinity of the first error detector, the second calculation means comprising:

a second adaptive filter for receiving the acoustic signal;

a second filter for receiving the acoustic signal; and

a second coefficient updator for receiving the output from the second adder and an output from the second filter, wherein:

an output from the second adaptive filter is input to the non-directional sound source;

the second coefficient updator updates a coefficient of the second adaptive filter by performing a calculation so that the output from the second adder is small; and

the second filter has a characteristic equal to a transfer function from the second error detector to the non-directional sound source.

29. An on-vehicle sound-amplification apparatus according to claim 24, wherein the acoustic tube of each of the at least two loudspeakers included in the dipole sound source is formed of a sound path having a desired bent shape.

30. An on-vehicle sound-amplification apparatus according to claim 29, wherein the at least two

loudspeakers included in the dipole sound source are arranged so that an interval between the respective acoustic radiation planes included in the acoustic tubes of the loudspeakers is less than or equal to approximately 1/2 of the wavelength of the reproduced sound.

31. A sound-amplification apparatus according to claim 1, wherein an acoustic radiation plane of the amplification-sound source and an acoustic radiation plane of the control sound source are placed such that a difference between a phase of the amplified sound and a phase of the control sound at a desired frequency is substantially within 90° in a direction along a main axis of acoustic radiation of the amplified sound.

32. A sound-amplification apparatus according to claim 13, wherein an acoustic radiation plane of the amplification-sound source and an acoustic radiation plane of the control sound source are placed such that a difference between a phase of the amplified sound and a phase of the control sound at a desired frequency is substantially within 90° in a direction along a main axis of acoustic radiation of the amplified sound.

33. An on-vehicle sound-amplification apparatus according to claim 21, the dipole sound source comprising an amplified sound source for radiating an amplified sound and a control sound source for radiating a control sound, wherein

an acoustic radiation plane of the amplification-sound source and an acoustic radiation plane of the control sound source are placed such that

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a difference between a phase of the amplified sound and a phase of the control sound at a desired frequency is substantially within 90° in a direction along a main axis of acoustic radiation of the amplified sound.